Handbook of Experimental Finance

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Supplementary material for Chapter 22

“Monetary policy and cash flow irregularity as drivers of asset price bubbles: an experimental study” by Dragana Draganac and Miloš Božović

APPENDIX A1. Assessment Test

Please, answer the following questions:

Are you willing to pay 1,000 for a stock which pays a dividend of 30 while the interest rate is 1%?

Are you willing to pay 1,000 for a stock which pays a dividend of 30 while the interest rate is 7%?

Regarding the previous two questions, which two rates of return are you going to compare?

When buying shares, which component of the total realised profit (dividend, interest, capital gain) do you lose, and which one do you gain?

When selling shares, which component of the total realised profit (dividend, interest, capital gain) do you lose, and which one do you gain?

Would you sell a stock at 1,000 if you bought it at 1,040 and realise a capital loss if the interest rate is 1% and there are only a few periods left till the end of the experiment?

Are you going to sell a stock at 1,000 if you bought it at 1,040 and realise a capital loss if the interest rate is 7% and there are only a few periods left till the end of the experiment?

Should you resell all the shares by the end of the experiment?

Are you more willing to invest in a stock with more irregular dividends when the interest rate is 1% or when it is 7%?

Are you more willing to borrow money when the interest rate is 1% or when it is 7%?

In which interest-rate treatment (1% or 7%) are you more willing to save money and less willing to trade shares?

Why are the initial share prices different between Stock 1 and Stock 2?

Why are the initial share prices lower in the treatment with 7% interest rate?

APPENDIX A2. Quantifying the Bubbles

Cointegration tests

We examine the existence of price bubbles using a cointegration test similar to Diba and Grossman (1988). In real markets, stock prices and dividends are typically non-stationary. If their first differences are stationary, and if prices and dividends are cointegrated of order (1, 1), the null hypothesis of a price bubble can be rejected. However, if prices and dividends are not cointegrated or if the first difference of price is non-stationary, we cannot immediately conclude that there is a price bubble. The non-stationarity of unobservable variables in market fundamentals can cause the absence of cointegration of prices and dividends. The non-stationarity of the first difference in price could result from the non-stationarity of first differences of unobservable variables. Also, the implicit assumption about dividends being generated by an ARIMA-type process may be wrong.

One of the assumptions of Diba and Grossman (1988) is that the discount rate is constant. They introduce a positive constant α that measures possible different valuations of expected dividends and expected capital gains. Current price is equal to the present value of the expected price and expected dividend in the next period. The price-dividend dynamics is therefore driven by a first-order difference equation:

$$P_t = \frac{1}{1+r}\mathbb{E}_t(P_{t+1} + \alpha D_{t+1} + u_{t+1}) \tag{2}$$

where P_t is the stock price at time t, r is the constant discount rate, D_{t+1} is the before-tax dividend paid between t and t+1, u_{t+1} is a random variable that investors observe, but researchers do not, while $\mathbb{E}_t$ is the expected value conditional on the information available at time t. If $\alpha = 1$ and $u_t = 0$ for all t, the rate of return will always be equal to r.

Assuming that the asset has no maturity (e.g. a stock) and that the term $\mathbb{E}_t(\alpha D_{t+1} + u_{t+1})$ has a growth rate lower than r, Equation (1) will have the following general solution:

$$P_t = F_t + B_t, \tag{3}$$

where the particular solution

$$F_t = \sum_{j=1}^{\infty} \frac{1}{(1+r)^j}\mathbb{E}_t\left(\alpha D_{t+j} + u_{t+j}\right) \tag{4}$$

is called the fundamental component, while the homogeneous solution

$$B_t = \frac{1}{1+r}\mathbb{E}_t(B_{t+1}) \tag{5}$$

is called the bubble component. If $B_t > 0$ for any t, there is a price bubble created by self-fulfilling expectations.

It is easy to verify that any solution to Equation (4) also satisfies the following stochastic difference equation:

$$B_{t+1} - (1+r)B_t = z_{t+1}, \tag{6}$$

where z_{t+1} is a random variable generated by a random process that satisfies $\mathbb{E}_{t-j}(z_{t+1}) = 0$ for all $j \geq 0$. It represents the innovation arising from new information available at $t+1$, that can be intrinsically irrelevant (i.e. unrelated to the fundamental component), or a fundamentally relevant variable that is not included in F_{t+1}.

If prices and dividends are non-stationary in levels, but stationary in their respective first differences, we can apply the Engle-Granger two-step procedure to test for cointegration of prices and dividends. Here, we again follow Diba and Grossman (1988) and create a series

$$P_t - \frac{\alpha}{r}D_t = B_t + \frac{\alpha}{r}\sum_{j=1}^{\infty}\frac{1}{(1+r)^j}\mathbb{E}_t\left((1+r)\Delta D_{t+j} + u_{t+j}\right) \tag{7}$$

The cointegrating vector is, therefore, $(1, -\alpha/r)$. The test consists of the following steps: 1) estimation of cointegrating vector; and 2) testing for the unit root of residuals from cointegrating regression of stock prices on dividends.

Bubble measures

We also use traditional bubble measure approach to investigate the size of stock turnover, presence of over- or underpricing of the stocks, and related effects. Bubble measures should be monotone in the difference between asset price and its FV and robust to any changes in experimental design, e.g. the total number of periods or changes in FV. According to Palan (2013b), bubble measures can be grouped into four categories: amplitude, deviation, duration and turnover measures.

<u>Amplitude measures</u>

Price Amplitude measures the spread between maximum and minimum relative mispricing. We will analyse two versions of this measure. The first one was introduced by King (1991):

$$PriceAmplitudeK = \max\left(\frac{\bar{P}_t - FV_t}{FV_1}\right) - \min\left(\frac{\bar{P}_t - FV_t}{FV_1}\right), \tag{8}$$

The second one was first used by Haruvy and Noussair (2006):

$$PriceAmplitudeHN = \max\left(\frac{\bar{P}_t - FV_t}{FV_t}\right) - \min\left(\frac{\bar{P}_t - FV_t}{FV_t}\right), \tag{9}$$

In Equations (8) and (9), $\bar{P}_t$ is a volume-weighted average stock price (VWAP) at time t, FV_1 is the stock's fundamental value at the beginning of the experiment, while FV_t is stock's fundamental value at time t. The only difference between these two bubble measures is in the denominator, i.e. the FV chosen for normalization. Both Price Amplitudes are always positive. One cannot conclude whether a stock is overvalued or undervalued solely based on Price Amplitude, which is regarded as one of its main disadvantages.

Crash is the measure of market collapse and is calculated as follows (see Razen *et al.*, 2016):

$$Crash = \min_{0<l<T-t^*}\left\{\frac{\bar{P}_{t^*+l} - FV_{t^*+l}}{FV_{t^*+l}}\right\} - \frac{\bar{P}_{t^*} - FV_{t^*}}{FV_{t^*}}, \tag{10}$$

where t^* denotes the period when the price reaches its maximum level, and T is the total number of periods. The size of the market collapse is calculated by subtracting the relative mispricing when the price reaches its peak from the minimum relative mispricing in the periods that follow.

Deviation measures

Total Dispersion (TD) is another measure of mispricing, given by:

$$TD = \sum_{t=1}^{T}\left|\tilde{P}_t - FV_t\right|, \tag{11}$$

where $\tilde{P}_t$ is the median price in period t. Since TD is defined as an absolute value, it will depend on the scale (i.e. the order of magnitude of price and the FV) and the total number of trading periods.

Average Dispersion (AD) is a measure of mispricing per period:

$$AD = \frac{1}{T}\sum_{t=1}^{T}\left|\tilde{P}_t - FV_t\right| \tag{12}$$

It is also dependent on the scale but independent on the total number of trading periods. Average Bias (AB) is a related measure:

$$AB = \frac{1}{T}\sum_{t=1}^{T}\left(\tilde{P}_t - FV_t\right), \tag{13}$$

where its sign informs us whether the stock is over- or undervalued.

Haessel's R^2 is obtained from an OLS linear regression of stock price on its FV. This measure becomes problematic if stock's price and its FV are related in a non-linear fashion, or if they are negatively correlated.

Relative Absolute Deviation (RAD), as introduced by Stöckl *et al.* (2010) has the following form:

$$RAD = \frac{1}{T}\sum_{t=1}^{T}\frac{|\bar{P}_t - FV_t|}{|\overline{FV}|} \tag{14}$$

RAD shows the extent by which average prices differ from the FV, as a fraction of the average FV. In this chapter, we also introduce a slightly modified version of Relative Absolute Deviation that is defined relative to the FV for the *same trading period*:

$$RAD_{mod} = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{\bar{P}_t - FV_t}{FV_t}\right| \tag{15}$$

Relative Deviation (RD) was also introduced by Stöckl *et al.* (2010). Unlike RAD, it captures the extent of either overvaluation or undervaluation:

$$RD = \frac{1}{T}\sum_{t=1}^{T}\frac{\bar{P}_t - FV_t}{|\overline{FV}|}. \tag{16}$$

In analogy to the modified RAD, we define:

$$RD_{mod} = \frac{1}{T}\sum_{t=1}^{T}\frac{\bar{P}_t - FV_t}{FV_t} \tag{17}$$

<u>Duration measures</u>

Bubble Duration (DUR) counts the maximum number of consecutive periods with an increasing deviation of stock's price from its FV. It was introduced by Porter and Smith (1995) as:

$$DUR = \max\left(m\colon \bar{P}_t - FV_t < \bar{P}_{t+1} - FV_{t+1} < \cdots < \bar{P}_{t+m} - FV_{t+m}\right) \tag{18}$$

The drawback of this measure is that it does not indicate the scale of the bubble, nor it is independent of the total number of periods in the experiment. Ackert *et al.* (2006) also added the condition that the VWAP must be higher than the fundamental value, $\bar{P}_t > FV_t$, for all periods t.

Relative Bubble Duration (RDUR) is calculated using the following formula:

$$RDUR = \frac{DUR - 1}{T - 2}. \tag{19}$$

It takes values from the [0,1] interval.

Boom Duration counts the highest number of successive periods during which the median price is higher than the fundamental value:

$$BoomDuration = \max\left(m\colon \tilde{P}_t > FV_t, \tilde{P}_{t+1} > FV_{t+1}, \dots, \tilde{P}_{t+m} > FV_{t+m}\right) \quad (20)$$

If the median price is always lower than the FV, the Boom Duration is equal to zero. Similarly, Bust Duration measures the highest number of successive periods during which the median price is *lower* than the fundamental value:

$$BustDuration = \max\left(m\colon \tilde{P}_t < FV_t, \tilde{P}_{t+1} < FV_{t+1}, \dots, \tilde{P}_{t+m} < FV_{t+m}\right). \quad (21)$$

If the median price is always higher than the FV, the Bust Duration is equal to zero.

Turnover

Turnover shows the number of shares exchanged during the experiment, normalized by the total number of shares:

$$Turnover = \sum_{t=1}^{T} \frac{q_t}{q}, \quad (22)$$

where q_t denotes the number of transactions in period t, while q is the total number of shares outstanding. Trade is expected to happen when subjects are rational but heterogeneous in terms of their risk-attitude. Therefore, stock trading should flow from more risk-averse to less risk-averse subjects. Palan (2013a) noticed that in experiments, stocks change hands more often than expected, which is sometimes interpreted as a sign of inefficient (experimental) markets.

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[1] Note that if there exists a particular t for which $B_t > 0$, then it must also be that $B_{t'} > 0$ for all $t' > t$ in order for Equation (4) to be satisfied recursively.